Reassessing the evidence for tree-growth and inferred temperature change during the Common Era in Yamalia, northwest Siberia.

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Supplementary Material

Extensive supplementary material is provided to document in the detail the tree-ring data, the temperature data, and the multiple stages of data processing and analysis, and this material is structured into the following nine documents. These, together with data files containing raw measurements, cross-dating reports, some figure datasets, adjustment logs, chronologies and reconstructions, are available at http://www.cru.uea.ac.uk/cru/papers/briffa2013qsr/. The temperature reconstruction data (including estimates of uncertainty) will also be submitted to the World Data Center for Paleoclimatology at http://www.ncdc.noaa.gov/paleo/data.html.

SM1. General approach to Chronology Construction (SM1_General.pdf)
SM2. Yamal region TRW analysis (SM2_YamalTrees.pdf)
SM3. Polar Urals region TRW and MXD analysis (SM3_PolarTrees.pdf)
SM4. Polar Urals trees consistency and adjustment (SM4_PolarRescale.pdf)
SM5. Polar Urals/Yamal chronology inter-comparisons (SM5_PolarYamal.pdf)
SM6. Chronology confidence (SM6_Uncertainty.pdf)
SM7. Climate associations with Polar Urals and Yamal chronologies (SM7_Climate.pdf)
SM8. Summer temperature inferences (SM8_Temperature.pdf)
SM9. “Greater Urals” large-regional analysis (SM9_GreaterUrals.pdf)

SM1: General approach to Chronology Construction
GA1. General approach to Chronology Construction adopted here
GA2. Specific Aspects of Chronology Construction and error representation adopted here
GA3. Signal-Free Terminology
GA4. References used in the Supplementary material

GA1 General approach to Chronology Construction adopted here
The general procedure followed here in applying RCS to the processing of measurement data from a wider region, as distinct from a more localised site location, or where measurements are drawn from different provenances (such as a mix of sub-fossil, archaeological contexts or living trees), involves a number of stages.

After confirming the cross-dating, the data are assessed as regards the presence of a medium to high-frequency common growth forcing signal using appropriate filtering. After showing there is a common signal at higher frequencies, the measurements are pooled together and processed using one-curve, signal-free RCS. Then for each of the separate provenances (site collections or other specified sub-sets of data), the signal-free measurements (i.e. generated from the single RCS curve) are averaged into separate provenance RCS curves and corresponding sub-chronologies. Any discrepancies between sub-RCS curves or between the sub-chronologies will highlight potential sources of bias in

RCS-generated chronologies. Having ensured the data sets are consistent (and presuming sufficient trees are available), the use of multiple RCS curves is tested; mainly to establish the consistency of chronologies developed from independent sets of faster and slower growing samples and to look for evidence of 'modern-sample bias'. Having reached this stage the probability distribution function (PDF) of tree indices can be examined and, where necessary, the tree indices can be transformed to have a normal distribution as described in the main text (see also Melvin and Briffa 2013). Estimates of uncertainty are routinely calculated for the full chronology and for separate frequency bands (generally 3: high, medium and low). Only then is the resulting chronology compared with measured climate data, again for discrete frequency bands. Finally, the chronologies are scaled on the basis of comparison with climate data to produce estimates of climate along with appropriate uncertainties.

GA2 Specific Aspects of Chronology Construction and error representation adopted here
In cases where multiple series of measurements exist for a tree, these were averaged together to produce 'mean-tree' series of measurements. The standardisation used here creates tree indices as ratios, i.e. measured values are divided by 'expected' growth values to produce tree indices. Simple arithmetic means are used in the creation of RCS curves and mean chronologies. Pith offset estimates are used in the creation of RCS curves and, where not available, the first measurement in a series is presumed to be ring age one. The signal-free method is used except where explicitly stated. RCS curves are created by smoothing the curve of mean signal-free measurements by ring age using an age-dependent low-pass spline (Melvin et al. 2007). The RCS smoothing curve is only applied where sample counts are greater than 3 and horizontal extension is applied to the poorly replicated final section of the mean measurement curve. For ring-width measurements the final third of the RCS curve is not allowed to rise, i.e. if a rise is detected then this is replaced by a horizontal extension of the RCS curve. Where multiple RCS curves are used, the trees are sorted into groups according to mean measurement size relative to the mean measurement size of a single RCS curve generated using all trees e.g. for ring-width measurements the relative growth rate is calculated as the radial increment of the tree divided by the radial increment of a single RCS curve calculated from all trees, both assessed over the common period of that tree's growth. Filtering is performed using smoothing splines (Cook and Peters 1981, Peters and Cook 1981) with a specified timescale (e.g. 20-years) that is the period for which the amplitude reduction is 50%.

The use of division to create RCS tree indices tends to produce tree indices with a more skewed distribution. Here we use an empirical method to transform the tree indices to have a normal distribution, which is described further in Melvin and Briffa (2013). When decomposing chronologies into discrete frequency bands (e.g. high-pass, low-pass or band-pass) division is used where indices are fractional deviations (skewed) and subtraction is used where indices have had their distribution converted to normal.

Unless otherwise explicitly stated (such as where the BCE, CE calendar convention is used) all plots and data files use the Astronomical Calendar, i.e. the year prior to 1 CE is the year zero and prior to this they are increasingly large negative year numbers.

The principal means of representing chronology confidence that we use in describing the various chronologies produced is the Standard Error of the mean (S.E.), usually shown as ±2 S.E. but calculated for the appropriate timescale of chronology variance represented (e.g. see Figure 9 of the main text). Expressed Population Signal (EPS) data are used to estimate high-frequency chronology confidence and “adjusted” EPS is used to assess the combined high- and low-frequency chronology confidence (see SM6 and SM9). We also employ bootstrap procedures in some instances (see SM9).

GA3 Signal-Free Terminology

The following is a summary of some key terms used in the main text and supplementary material:

(1) "Raw measurements" are unadjusted measurement data (here mostly the average of raw measurements from multiple cores taken from one tree) in appropriate units (e.g. mm for TRW or $g.cm^{-3}$ for MXD).

(2) "Expected growth" is an empirical estimate of the expected TRW or MXD values expressed with regard to ring age (here the RCS curve values).

(3) "Tree indices" are obtained by removing the expected growth from measurements (i.e. raw measurements are divided by the RCS curve values at the appropriate age).

(4) "Chronology indices" are an average of all tree indices for each year of the chronology across all (or a sub-sample of) trees at the site.

(5) "Signal-free measurements" are measurements that have been divided by chronology indices - this has the effect of removing the common growth signal from the measurements, leaving behind variations related to ring age and random and systematic differences between trees (i.e. the measurement series that would be expected in an unchanging climate).

(6) "Signal-free tree indices" are tree indices that have been divided by chronology indices - this has the effect of removing the common growth signal from the indices, leaving behind only random and systematic differences between trees. Signal-free tree indices are useful for trying to identify systematic differences between sites or sub-samples of trees. Were this comparison made using measurements it would be confused by the different age structures and time spans (i.e. different climate conditions experienced) of the two data sets. The use of signal-free tree indices removes the effects of both of these confounding signals.

The “Signal-Free RCS method” (SF RCS) creates a chronology with index values for each year.

The average by year of “signal-free tree indices” is a null chronology (with zero variance), not to be confused with the SF RCS chronology.

GA4 References used in the Supplementary material.

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